MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

DET5038 – POWER ELECTRONICS

(Diploma in Electronics Engineering)

29 FEBRUARY 2020
2:30 PM – 4:30 PM
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of **6** pages excluding the cover page and appendix.
2. Answer ALL questions. All necessary working steps must be shown.
3. Write all your answers in the answer booklet provided.

QUESTION 1 [20 marks]

(a) MOSFET is a type of transistor used in power semiconductor switches.

(i) Draw the I-V characteristic graph of a n-channel power MOSFET with the appropriate labeling to specify the ohmic region, active region and cutoff region of the MOSFET.

(6 marks)

(ii) Based on the graph in part (i) describe for the MOSFET parameter of BV_{DSS}, I_{DSS}, $V_{GS(TH)}$ and $R_{DS(ON)}$.

(4 marks)

(b) A single phase half wave rectifier is used to transform AC waveform to DC pulsating waveform.

(i) Draw a single phase half wave rectifier with inductive load circuit. Explain the operating principle of the circuit.

(5 marks)

(ii) Draw the graph of input voltage (V_S), output voltage (V_O), output current (I), resistor voltage (V_R), inductor voltage (V_L) and diode voltage (V_{diode}).

(5 marks)

Continued ...

QUESTION 2 [20 marks]

(a) A DC-DC converter circuit is used to produce an output voltage of 120V to power a water heater from an input voltage of 30V produce by a solar panel.

(i) Name the type of DC-DC converter used.

(1 mark)

(ii) Sketch the circuit diagram of the converter.

(3 marks)

(iii)Explain the operating principle of the converter specified in (i).

(5 marks)

(b) Draw the circuit diagram of a push-pull inverter. State two advantages of this circuit.

(5 marks)

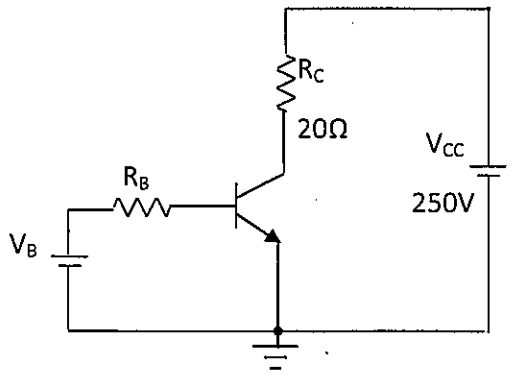
(c) Sketch the equivalent circuit diagram for all three modes of operations for a simple series resonant inverter.

(6 marks)

Continued ...

QUESTION 3 [20 marks]

A power BJT is used as a switch to energize a resistive load (R_C) as shown in Figure 1. Assume that the transistor on state time is thrice of the off state time at a switching frequency of 200 kHz.



$V_{CE(sat)} = 2$ V

$V_{BE(sat)} = 3$ V

$V_{BE(on)} = 0.7$ V

$I_{C(leak)} = 3$ mA

$\beta = 20$

$\tau_{on} = \tau_{off} = 0.1\mu s$

Figure 1

By using the provided data, find the following:

(i) On state time and off state time.

(5 marks)

(ii) Static power loss.

(9 marks)

(iii)Dynamic power loss.

(4 marks)

(iv)Total power loss.

(2 marks)

Continued ...

QUESTION 4 [20 marks]

(a) A single phase full wave uncontrolled rectifier is connected to a 150 Ω resistor. Assuming the circuit is operating from a 240 V_{peak}, 50 Hz supply, calculate:

(i) Average output voltage.

(2 marks)

(ii) RMS output voltage.

(2 marks)

(iii) Ripple voltage.

(2 marks)

(iv) Ripple voltage factor.

(2 marks)

(v) Average output current.

(2 marks)

(b) A buck-boost converter generates an output voltage of 48 V across a 20 Ω resistor from an input voltage of 12 V. The output ripple voltage must be less than 1 V at a switching frequency of 1500 Hz under continuous conduction mode. Determine the following parameters:

(i) The input and output power.

(4 marks)

(ii) The duty ratio.

(1 mark)

(iii) The inductance value.

(2 marks)

(iv) The capacitance value.

(3 marks)

Continued ...

QUESTION 5 [20 marks]

(a) A full-bridge pulse width modulator inverter operates from a 120V DC power supply. The inverter has a frequency of 2kHz and a duty cycle of 80%. Find the:

(i) RMS value of the total output voltage.

(1 mark)

(ii) RMS output voltage of the fundamental component.

(2 marks)

(iii) RMS output voltage of total harmonic component.

Hint: $V_{H,rms} = \sqrt{DV_S^2 - \frac{8V_S^2}{\pi^2}\sin^2\frac{1}{2}D\pi}$

(3 marks)

(iv) Total harmonic distortion.

Hint: $THD = \sqrt{\left(\frac{V_{o,rms}}{V_{1,rms}}\right)^2 - 1}$

(2 marks)

(v) Voltage transfer ratio.

(1 mark)

(vi) Harmonic factor of 1st harmonic.

(1 mark)

Continued ...

(b) Figure 2 shows a half bridge resonant converter with a unidirectional switch with initial capacitor voltage, $V_{C0} = 170V$ at t = 0.

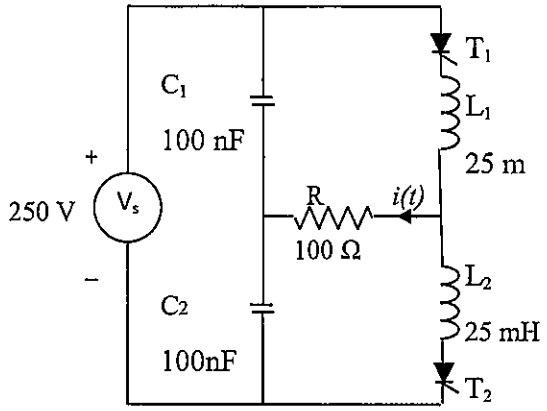


Figure 2

Calculate the following:

(i) Damping factor, α.

(3 marks)

(ii) Angular resonant frequency, ω_o.

(2 marks)

(iii) Angular ringing frequency, ω_r.

(2 marks)

(iv) Instantaneous load current expression, $i(t)$, given

Hint:

$$i\ (t) = \frac{V_s + V_{C0}}{L\omega_r} e^{-\alpha t} \sin \omega_r t$$

(3 marks)

End of Page.

APPENDIX

Table 1 Switching power loss of power BJT

	Resistive Load	Inductive Load
ON state	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$
OFF state	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{6T}$	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{2T}$
Turn Off	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{6T}$	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{2T}$

Table 2 Switching power loss of power MOSFET

	Resistive Load	Inductive Load
ON state	$P_{on} = I^2_{D(on)} R_{DS(on)} \frac{t_{on}}{T}$	$P_{on} = I^2_{D(on)} R_{DS(on)} \frac{t_{on}}{T}$
OFF state	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{6T}$	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{2T}$
Turn Off	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{6T}$	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{2T}$

Table 3 Useful equations of DC to DC converters

Buck Converter	Boost Converter	Buck-Boost Converter
$V_o = DV_s$	$D = 1 - \frac{V_s}{V_o}$	$D = \frac{V_O}{V_s + V_O}$
$I_L = \frac{V_o}{R}$ $(\Delta i_L)_{close} = \frac{V_s - V_o}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$	$I_L = \frac{V_s}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_s}{L} DT$ $(\Delta i_L)_{open} = \frac{V_S - V_o}{L}(1-D)T$	$I_L = \frac{V_s D}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_S}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$
$L = \frac{(1-D)R}{2f}$	$L = \frac{D(1-D)^2 R}{2f}$	$L = \frac{(1-D)^2 R}{2f}$
$C_{min} = \frac{1-D}{8Lf^2 \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$